Use of Outpatient Clinics as a Health Indicator for Communities around a Coal-Fired Power Plant

Ayana I. Goren,[1] Sarah Hellmann,[1] and Eduard D. Glaser[2]

[1]Institute for Environmental Research, Ministry of the Environment and Sackler School of Medicine,Tel-Aviv University, Tel-Aviv, Israel; [2]Association of Towns for Environmental Protection, Hadera, Israel

The permit to operate the first coal-fired power plant in Israel was issued with the condition that a comprehensive network to monitor its effects on the environment, health, and agriculture must be installed and operated around the plant. The health monitoring system consists of four studies, which started 1 year prior to the operation of the plant and were carried out for 10 years. In the framework of the health monitoring system, a study of requests for health services was carried out. In this survey, 8 clinics of the Sick Fund, served by 16 physicians, were followed up. The clinics were located as near as possible to air pollution monitoring stations and represent expected different levels of pollution. A health recorder summarized each day's visits to each physician and tabulated the total visits for each day and the visits due to respiratory tract complaints. Multivariate stepwise regressions on total as well as on respiratory complaints were carried out. The independent variables in the regressions were sulfur dioxide, meteorological parameters (such as temperature and humidity), and flu epidemics. Temperature was almost always significantly correlated with respiratory complaints, but less correlated with total visits among adults and children. Sulfur dioxide, most meteorological parameters, and flu epidemics were not meaningful explanatory factors in the regressions. Ambient air pollution levels did not exceed the Israeli air quality standards or the more stringent local air quality standards; the monthly and annual average sulfur dioxide and nitrogen oxides values were very low. *Key words:* air pollution, community study, outpatient clinics, pediatrics, pulmonary diseases. *Environ Health Perspect* 103:1110–1115(1995)

The permit to build and operate the first (1400 megawatt) coal-fired power plant in Israel stipulated that a comprehensive network be installed to monitor its effects on the environment, health, and agriculture. An epidemiological monitoring program was designed in response to the health monitoring requirement (*1*).

Four types of studies were included in the epidemiological monitoring program: mortality analyses, monitoring of requests for health services, studies of pulmonary symptoms and lung function in schoolchildren, and panel studies of adults, both with and without chronic obstructive pulmonary diseases. Baseline data were gathered for at least 1 year prior to the operation of the first unit of the power plant. Subsequent data were collected until the end of 1990.

This epidemiological monitoring program was aimed at detecting any spatial or temporal changes in the health status of the study population, taking into account possible confounding factors (such as meteorological parameters and flu epidemics) that could act similarly to air pollution. Here we evaluate requests for health services in outpatient clinics. This survey was designed to point out short-term health effects with minimal time delay. Ongoing analysis of the data could demonstrate a difference in demand for medical services between areas with different levels of pollution.

Baseline data gathered before the operation of the power plant enabled a comparison with the seasonal distribution of visits before possible changes in air quality.

Methods

About 70,000 people live within a 10-km radius of the power plant. The population in this area was relatively stable throughout the time of the follow-up. About 80% of this population was insured under "The General Sick Fund." The use of health services in 8 clinics of the Sick Fund, served by 16 physicians (each clinic has one pediatrician for children younger than 14 years and one general physician for adults) was recorded. The size of the physicians' practices did not change substantially over the years of the follow-up. The number of patients in each of the clinics followed up varied from 600 to 2100. In the area expected to be most polluted, about 7000 patients were followed up. The total number of patients followed up in this study was about 30,000 persons.

The distribution of the eight clinics represent a gradient of expected low, medium, and high pollution, according to the environmental impact statement presented by the Israel Electric Company to the Ministry of Health. The clinics were located as near as possible to continuous air pollution monitoring stations (Fig. 1). The people using these clinics lived in the vicinity; therefore, the location of the clinics served as a good estimate of exposure to air pollutants in the community. The physicians kept records, registering all visits of patients and each patient's diagnosis.

Once a week, a health recorder summarized each day's visits to each physician and separately tabulated the total visits for each day as well as the number of visits for respiratory tract complaints. Air pollution and meteorological data were gathered and analyzed by the Association of Towns for Environmental Protection.

The environmental monitoring network consists of 12 monitoring stations, of which 10 are stationary and 2 are mobile. The monitoring stations are fully automatic and measure the following data: SO_2, NO_x, O_3, CO, total hydrocarbons, and meteorological parameters. Not all monitoring stations perform all measurements. The instruments are automatically calibrated and continuously measure the levels of ambient air pollution. The data are sent by radio to the Association of Towns and fed into a computer that stores and analyzes them. Daily averages of air pollution measurements were given to the health recorder for inclusion in the statistical analysis of visits to outpatient clinics.

Data concerning flu epidemics during November to April of each year were gathered nationwide by the epidemiological department of the Ministry of Health. Most flu cases were diagnosed on symptomatology. A combined file was created including daily visits to outpatient clinics, daily air pollution concentrations, daily meteorological data, and daily flu data.

Statistical analysis of use of outpatient clinics in the vicinity of the power plant was carried out using SPSS (McGraw-

Address correspondence to A. Goren, Institute for Environmental Research, Sackler School of Medicine, Tel-Aviv University, Tel-Aviv 69978 Israel.

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Hill, New York) and BMDP (Berkeley, California) programs. The ratio between the daily number of visits and the size of the physician's practice (size = number of patients assigned by the Sick Fund to the physician) (visit ratio) was calculated both for visits with respiratory tract complaints and for the total number of visits, for every day and physician. The daily averages of these ratios for each day of the week and for each month were calculated. The calculations were carried out separately for visits to pediatricians and for visits to general physicians.

Monthly averages for all the survey years were calculated from the daily averages, both for respiratory diseases and for the total number of visits among children and adults. In the next step, data of environmental measurements from the nearest monitoring stations were added to the database of the outpatient clinics.

From flu monitoring data, daily averages of flu visits were calculated for children and for adults. These flu data were also added to the database of the outpatient clinics. Multivariate stepwise regressions on the daily visit ratios were performed separately for each year of the study for both pediatricians and general physicians. Daily visits due to respiratory tract complaints as well as visits due to all reasons were the dependent variables in the multivariate analysis. Daily ambient SO_2 concentrations, meteorological parameters, and flu-data were the independent variables in these regressions. To follow up possible changes over time in the use of outpatient clinics, a one way analysis of variance was carried out, in which the studied effect was the year of study. The meteorological parameters as well as SO_2 were entered as covariates in the analysis of variance.

Results

Analysis of the daily averages of visit ratios showed an increased use of clinics on Sundays, the first workday of the week in Israel. This trend characterized both visits to pediatricians and visits to general physicians.

In Figures 2 and 3 the visit ratios for monthly averages of total visits and of visits due to respiratory tract complaints are presented. Analysis of monthly averages of outpatient clinic visits showed seasonal trends.

Among adults, a seasonal trend of more frequent use of outpatient clinics due to respiratory tract complaints was observed during the months December through March throughout the follow-up. A seasonal trend of more frequent use of pediatric outpatient clinics during winter months due to respiratory tract complaints was also observed (Fig. 3). A seasonal trend was not observed for the total visits to practices served by general physicians (Fig. 2). However, the total number of visits to pediatricians peaked during winter months, possibly because respiratory complaints account for a major part of the total visits to pediatricians.

No consistent trend of change in the use of adult clinics due to respiratory tract complaints was observed between 1982 and 1990. A substantial decline in

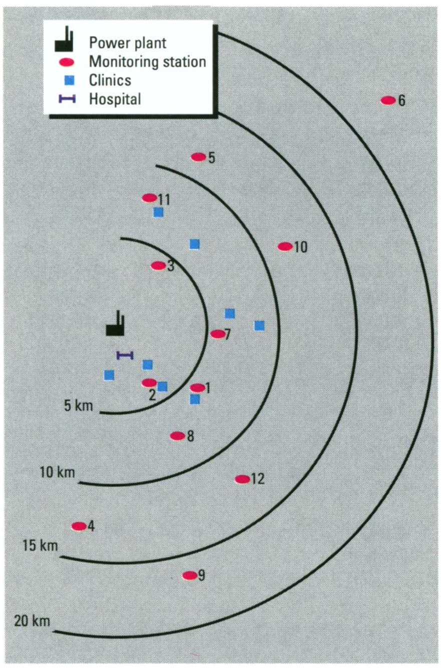

Figure 1. Site of the power plant, outpatient clinics, and environmental monitoring stations. Station 11, expected low pollution; station 2, expected medium pollution; station 7, expected high pollution.

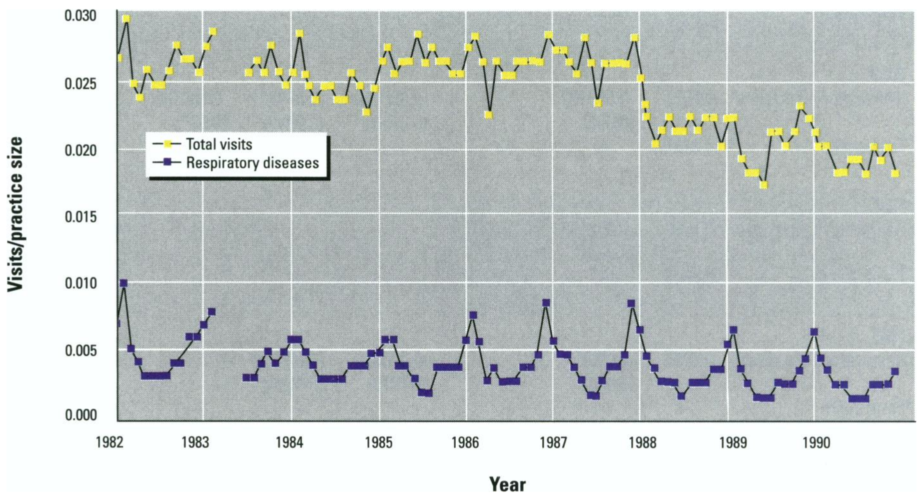

Figure 2. Monthly averages of clinic visits by adults, expressed as a ratio to the size of physicians' practices.

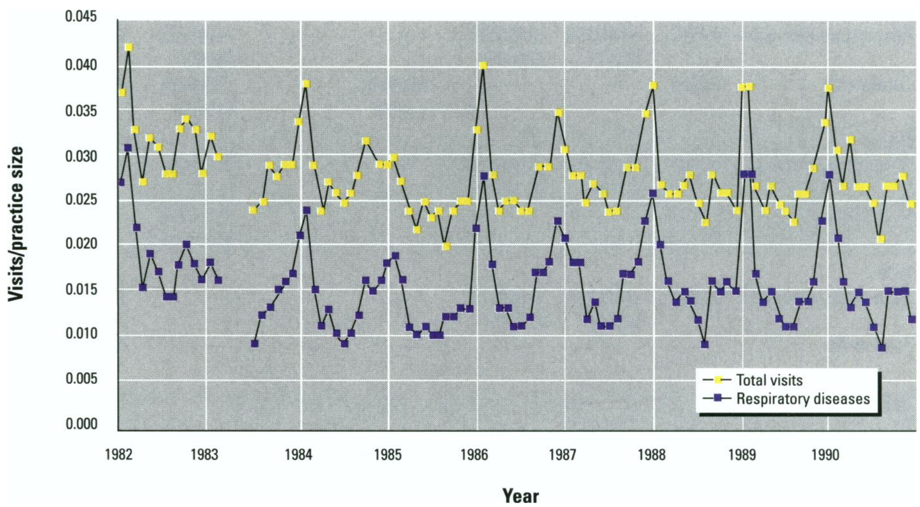

Figure 3. Monthly averages of clinic visits by children, expressed as a ratio to the size of physicians' practices.

the total number of visits occurred between 1988 and 1990 (Fig. 2). For children, a trend of moderate decline in the total number of visits, and especially in the number of visits due to respiratory tract complaints, was observed between 1982 and 1984. There is no obvious trend for the following years (Fig. 3).

Multivariate statistical analyses were carried out to determine the dominant environmental factors explaining the use of medical services in the power plant area. By means of multiple stepwise regressions, the effects of meteorological parameters (such as temperature, barometric pressure, humidity, and precipitation), flu epidemics, and air pollutants on the use of outpatient clinics were analyzed.

For each year of study, a multiple regression analysis which included all the above-mentioned parameters was carried out. Regression equations were calculated separately for respiratory complaints and for total visits, both for children and adults. The coefficients for the variables which appeared in the regression equations are presented in Table 1 for each year of the study. The major explanatory factor for use of outpatient clinics among both children and adults was ambient temperature. Most coefficients for temperature were negative and highly significant; i.e., at lower temperatures, higher numbers of clinic visits were observed. In some regressions, further explanatory factors for use of medical services occurred; a flu epidemic was the most frequent additional explanatory factor. The part of the variance explained by the regressions was between 6% and 32%.

In the analysis of changes in use of outpatient clinics over time, the year of follow-up was entered as the main effect, and all other variables such as tempera-

Table 1. Coefficients in the regression equations for respiratory diseases and for total number of visits among children and adults[a]

Dependent variable	Adults						Children					
	R^2	Temperature	BP	Precipitation	SO_2	Flu epidemics	R^2	Temperature	BP	Precipitation	SO_2	Flu epidemics
1982												
Respiratory diseases	0.2279	0.000296 (0.000)	—	—	—	0.000043 (0.0035)	0.0595	-0.000688 (0.000)	—	—	—	—
Total visits	—	—	—	—	—	—	0.0154	—	—	—	—	0.000262 (0.0010)
1983												
Respiratory diseases	0.2522	-0.000182 (0.000)	—	-0.000112 (0.0053)	0.084721 (0.0003)	0.000303 (0.000)	0.1005	-0.000399 (0.000)	-0.000115 (0.0270)	—	—	—
Total visits	0.0167	—	—	—	—	-0.000444 (0.0001)	0.0280	-0.000374 (0.0001)	—	—	—	—
1984												
Respiratory diseases	0.1588	-0.000195 (0.000)	0.000047 (0.0294)	—	—	—	0.3246	-0.000483 (0.000)	0.000179 (0.0197)	—	—	0.000352 (0.000)
Total visits	0.0048	—	0.000152 (0.0143)	—	—	—	0.1490	—	0.000416 (0.000)	—	—	0.000423 (0.000)
1985												
Respiratory diseases	0.1665	-0.000214 (0.000)	—	-0.000025 (0.0273)	0.061329 (0.0134)	—	0.1924	-0.000352 (0.000)	—	—	—	0.000170 (0.000)
Total visits	—	—	—	—	—	—	0.0580	—	—	—	—	0.000293 (0.000)
1986												
Respiratory diseases	0.2256	-0.000301 (0.000)	—	—	—	0.000054 (0.0218)	0.2907	—	0.000521 (0.000)	0.000204 (0.0035)	0.26535 (0.0172)	0.000306 (0.000)
Total visits	0.230	—	—	—	—	-0.000239 (0.000)	0.2038	0.00068 (0.0006)	0.000849 (0.000)	0.00032 (0.0020)	—	0.000473 (0.000)
1987												
Respiratory diseases	0.1819	-0.000156 (0.000)	0.000075 (0.0069)	—	—	0.000192 (0.000)	0.1503	—	0.000425 (0.000)	—	—	-0.000189 (0.000)
Total visits	0.0105	—	—	-0.000213 (0.0450)	—	0.000232 (0.0105)	0.0671	0.000319 (0.0029)	0.000459 (0.0001)	—	—	0.000228 (0.000)
1988												
Respiratory diseases	0.1695	-0.000114 (0.000)	0.00001 (0.0068)	—	—	0.000166 (0.000)	0.1903	-0.000348 (0.000)	—	-0.000251 (0.0148)	-0.236965 (0.0001)	0.000287 (0.000)
Total visits	0.0090	—	—	—	—	0.000246 (0.0010)	0.1341	—	—	-0.000262 (0.0270)	-0.148155 (0.0474)	0.000395 (0.000)
1989												
Respiratory diseases	0.2066	-0.000234 (0.000)	-0.000119 (0.2111)	—	—	—	0.2575	-0.00105 (0.000)	-0.000615 (0.0146)	—	—	—
Total visits	—	—	—	—	—	—	0.1383	-0.000838 (0.0002)	—	—	—	—
1990												
Respiratory diseases	0.1948	-0.000291 (0.000)	—	—	—	—	0.2405	-0.000671 (0.0001)	—	—	—	0.000334 (0.0050)
Total visits	—	—	—	—	—	—	0.1451	-0.00052 (0.0219)	—	—	—	0.000421 (0.0075)

BP, barometric pressure.
[a]*p*-value for the variable in regression equation in parentheses.

ture, precipitation, barometric pressure, and SO_2 were entered as covariates. Significant deviations from the average use of pediatric and adult outpatient clinics occurred over time, but the effect of the year of study was not consistent. In other words, a significant increase in use of outpatient clinics was observed for some years, while in other years a decrease was observed.

During the time period of the study, the ambient air pollution levels did not exceed the Israeli air quality standards or the more stringent local standards (half of the Israeli standard), based on measurements of SO_2 and NO_x at the 12 monitoring stations (Fig. 1). In fact, the annual average SO_2 and NO_x values were very low. For instance, the 1989 annual SO_2 averages did not exceed 20 µg/m^3, less than a quarter of the U.S. standard, at any monitoring station (Table 2).

Table 2. Monthly and yearly average sulfur dioxide concentrations (µg/m^3) for 10 monitoring stations in 1989

Station	1	2	4	5	6	7	8	10	11	12
January	7	19	8	12	20	7	11	8	0	5
February	5	17	9	15	26	13	8	11	11	6
March	5	12	5	5	15	13	7	7	5	5
April	7	23	8	13	32	12	10	14	23	9
May	9	21	11	10	16	13	5	9	8	8
June	10	21	8	14	13	5	11	7	7	9
July	11	8	4	5	5	18	5	11	0	10
August	13	7	4	5	8	23	8	10	1	10
September	11	11	4	6	4	10	6	7	1	11
October	12	12	12	10	9	7	6	8	7	5
November	5	11	7	10	11	12	4	7	6	5
December	6	19	14	14	18	15	5	11	22	20
Yearly average	8	15	8	10	15	12	7	9	8	9

Because of the difficulty of following multiyear trends of such low levels of annual average concentrations, we decided to focus on half-hourly concentrations, for which there is also an Israeli ambient standard. We counted the number of air pollution "events" in which the half-hourly averages for SO_2 or NO_x were above an arbitrary threshold. The threshold values chosen were 183 µg/m^3 (70 ppb) for SO_2 and 235 µg/m^3 (125 ppb) for NO_x, which are about one-quarter of the local air quality standards and about one-eighth of the Israeli air quality standards. In Figure 4 the summary of events for SO_2 and for NO_x during 1981–1992 is presented. From this summary, an increase in the total number of events measured by the monitoring stations can be observed. Part of the increase in the number of events originated from the operation of the power plant, but the main increase was connected with other sources, such as industry and especially traffic.

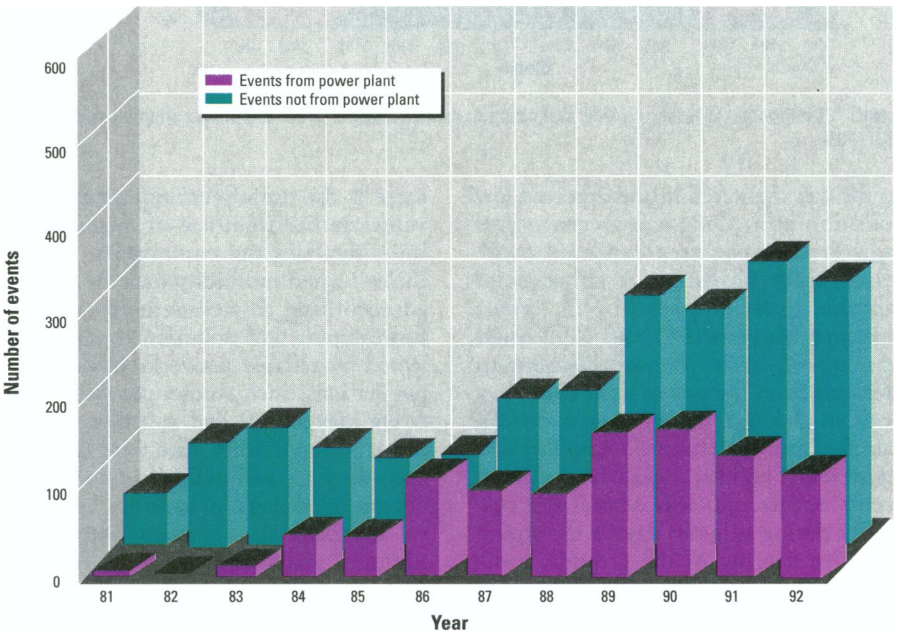

Figure 4. Summary of sulfur dioxide and nitrogen oxides "events" measured at 10 permanently sited monitoring stations during the period 1981–1992.

The sources responsible for the events were identified according to the wind direction measured at the time of the event. The highest number of SO_2 events from the power plant was measured at the monitoring station located in the area expected to be most polluted (Fig. 5); a markedly lower number of events was registered in the area expected to be moderately polluted. No events were registered during 1987–1992 in the monitoring station located in the expected low-pollution area. The highest number of NO_x events from all sources was measured in the monitoring station located in the area expected to be most polluted (Fig. 6); a markedly lower number of

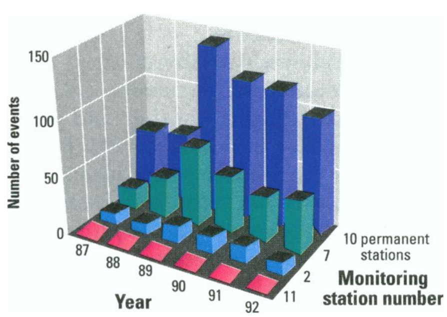

Figure 5. Sulfur dioxide "events" from the power plant in expected low-pollution (station 11), medium-pollution (station 2), and high-pollution (station 7) areas and for the 10 permanently sited monitoring stations during 1987–1992.

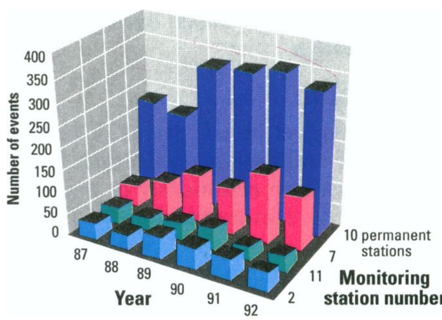

Figure 6. Nitrogen oxides "events" measured around the power plant in the expected low-pollution (station 11), medium-pollution (station 2), and high-pollution (station 7) areas and for the 10 permanently sited monitoring stations during 1987–1992.

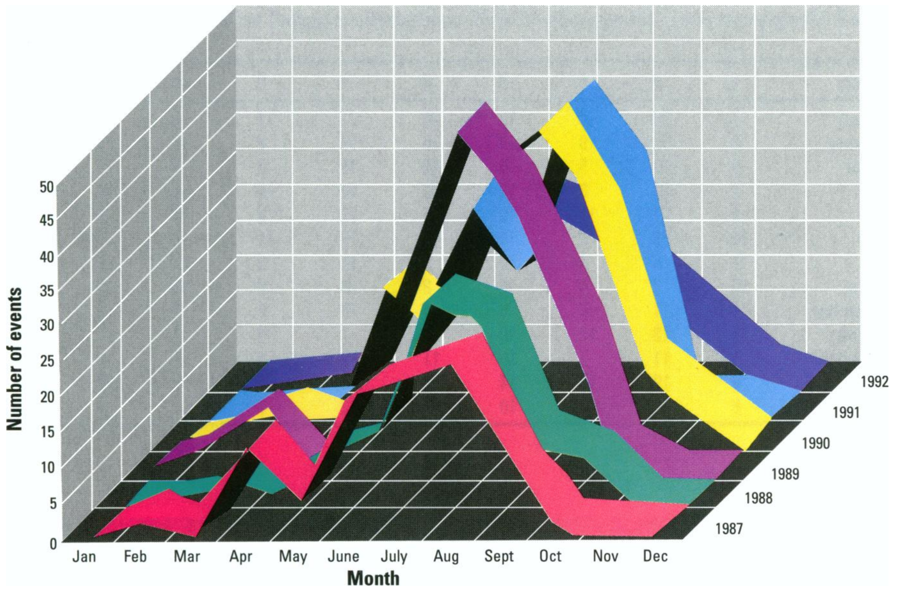

Figure 7. Distribution of sulfur dioxide and nitrogen oxides "events" from the power plant by month during 1987–1992.

events was registered in the expected low pollution area. Only a few events were registered in the area expected to be moderately polluted. A substantial increase in the number of NO_x events measured between 1987 and 1992 could be observed. In the monthly distribution of events from the power plant (Fig. 7), a peak in the number of events during summer months (June–September) was registered. The reason that the pollution events occurred at this coastal site primarily during summer days is the strong radiative heating of the ground, combined with an on-shore sea breeze (3–5 m/sec), which together gave rise to a strong convective layer extending to a height of several hundred meters. When the plumes from the high stacks entered the convective layer, fumigation occurred and pollution was brought down to ground level. In contrast, no significant convective layer developed during typical winter weather.

Discussion

Epidemiological investigations of health effects of ambient air pollution have often focused on community or regional morbidity and mortality (*2–4*). Short-term effects on morbidity have been sought by examining correlations of pollution levels based on networks of monitoring stations with rates of hospital admissions (*3-6*), emergency room visits (*2,7–10*), or outpatient clinic visits (*11–13*). Such community-based epidemiological studies are subject to a number of limitations; primary among these is the use of community exposure values rather than use of exposures of individuals in the community. Nevertheless, when morbidity data are collected according to well-defined and uniform criteria and pollution data are collected by reliable networks of monitoring stations, such studies provide a relatively inexpensive and valuable tool. In our study morbidity data were collected according to well-defined and uniform criteria. However, we have not been able to distinguish between acute and planned visits nor could we identify multiple visits of the same patients. Air pollution data were collected by a reliable network of monitoring stations, located in the vicinity of the Sick Fund clinics. All available data collected over the entire follow-up period have been used in the analysis. Regarding air pollutants, past studies have measured primarily airborne SO_2 and particulate matter arising from industries.

In highly industrialized areas, SO_2 and particulate concentrations are well correlated with one another and with some detectable health effects (*3*). In the vicinity of the Hadera power plant, particulate matter has only been measured by weekly high-volume sampling. No measurements of small-diameter particulate matter have been carried out by the monitoring network in the power plant area. Microscopic analyses of high-volume samples have shown that particulates in this region mainly originate from natural sources. This is due to the soils and vegetation and to the use of electrostatic precipitators which reduce fly ash emissions from the power plant to low levels. Sulfur dioxide concentration alone has therefore been taken in this study as a rough estimate of health-related environmental pollution resulting from the power plant. Meteorological data have been almost complete, and all available data were used in the multivariate analysis. Similar to our findings, Kardaun et al. (*11*), in their study in Amsterdam, showed seasonal variations in the use of family practices. Marty (*12*), in a Swiss study, showed an increase in acute respiratory illnesses among children during fall and winter months (low temperatures, high humidity) similar to our results. Bates et al. (*7*) have found variations in emergency visits by day of the week, similar to our findings of excess visits on Sundays. The excess emergency room visits on Sundays observed by Bates may have resulted from lack of health services in the community on Sundays, while excess in outpatient clinic visits on Sundays in our study are apparently due to use of the first opportunity to consult a community physician after the weekend. The trend of moderate decline in the utilization of "The General Sick Fund" medical services during the years of this study may have resulted from consulting more often private pediatricians instead of using the Sick Fund medical services.

Kucerova et al. (*13*) also used morbidity data as recorded by pediatricians in the community. They registered a higher incidence of respiratory diseases ($p<0.01$) with higher mean duration for contaminated versus clean areas. In our survey we could not find an effect of SO_2 exposure on use of outpatient clinics, apparently due to extremely low SO_2 levels even in the regions expected to be more polluted. Moreover, the number of events of SO_2 peaked during summer months, whereas visits due to respiratory complaints peaked during winter months.

Similar to our findings, Rebmann et al. (*14*), in their health study carried out among preschool children in southwestern Germany, did not find a correlation between cases of croup and the degree of air pollution, apparently because of relatively low pollution levels. The epidemiological monitoring program carried out in the vicinity of the Hadera power plant, included a health study among schoolchildren in which pulmonary symptoms and lung functions had been assessed. In the framework of this study we also could not show any deleterious health effect among the children residing in the areas expected to be affected by the operation of the power plant as compared to the expected low-pollution areas. Even among the most sensitive part of the population, adults suffering from chronic obstructive pulmonary diseases, the follow-up failed to show any deterioration in their lung function or differences in the severity of their respiratory complaints as compared to a panel of a similar population residing in a rural, clean area with no major environmental polluting source. Air pollution levels measured around the coal-fired power plant in Hadera were low and did not seem to cause adverse health effects.

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